here developed can be applied to the movements of the ocean just as to those of the atmosphere. In the ocean the temperature and the saltness play the same part in changing the density as do the temperature and the moisture in the case of the atmosphere. Eventually the theory also retains its applicability when we consider the atmosphere and the ocean together as one fluid medium. This is of great importance because of the extensive interaction between the movements of the air and of the ocean. Hence an excellent opportunity for the simultaneous solution of great meteorological and hydrographic problems will be afforded if the plans projected at the Hydrographic Congress in Stockholm in 1899 can be realized, so that the hydrographic expeditions sent out many times yearly by the participating nations can also carry meteorologists with instruments for the investigation of the upper strata of the air. In this respect the North Atlantic Ocean in the autumn and winter will offer especial interest. Perhaps it will here be possible to study the development of cyclones that probably often form over the region of the Gulf Stream, and therewith simultaneously measure the quantity of heat given out by the ocean and consumed in cyclonic formation.

THE PORTO RICAN HURRICANE OF 1899.

By C. O. PAULLIN, Nautical Expert, United States Hydrographic Office.

Soon after the occurrence of the Porto Rican hurricane of 1899, the United States Weather Bureau published a complete account of the passage of this storm through the West Indies and along the American coast. The daily maps of conditions over the Atlantic Ocean, compiled by the United States Hydrographic Office from the reports of its voluntary observers, make it possible to furnish some additional information of exceptional interest to meteorologists concerning this storm, both previous and subsequent to the period of its history covered by the Weather Bureau.

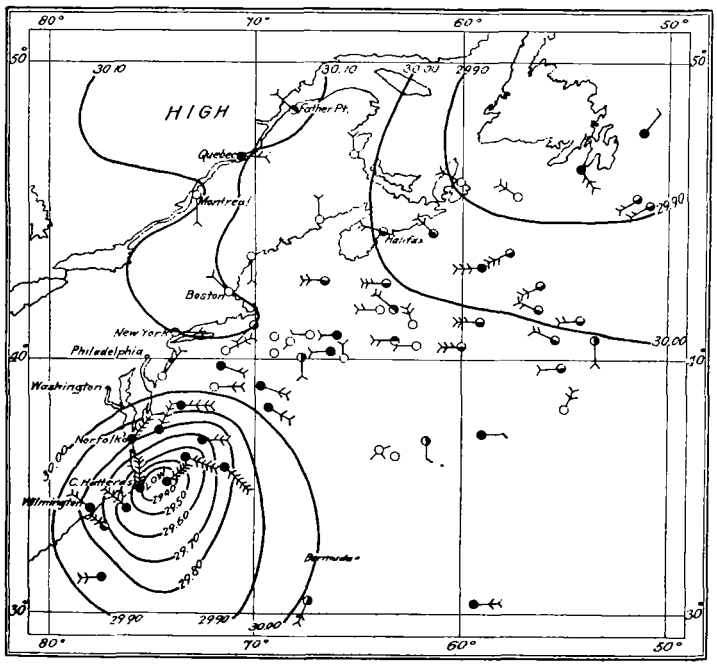

FIG. 13.—Greenwich noon, August 17, 1899.

The tropical storms of the North Atlantic generally originate to the eastward of the Lesser Antilles within the belt of calms which covers the ocean from latitude 5° to 15° north. Owing to the scarcity of observing vessels in this part of the Atlantic, and the relatively small area which the hurricane here attains, reports of these storms to the eastward of the fiftieth meridian are seldom received. Information concerning tropical storms at or near their place of origin is, consequently, almost wholly lacking, and much interest attaches to the report of the British steamship *Grangense*, which vessel encountered the late hurricane 1,800 miles east by south of the Island of Guadeloupe. The *Grangense* passed through the center of the storm and took very careful and complete observations, warranting the publication of her log in full, as follows:

At noon of August 3, when in latitude 11° 51′ north, longitude 35° 42′ west, we experienced a sudden change in the weather, which, being most unusual in this part of the world, is worthy of note. Early in the afternoon the barometer began slowly to fall from 29.93 inches. At 2 p. m. it stood 29.73, the sky becoming overcast with cumulo-nimbus clouds and the wind freshening to a moderate gale from north-northwest. At 4 p. m. the barometer read 29.53 inches, the wind remaining from the same direction with force increased to a fresh gale, accompanied with heavy rain. At 5 p. m. the barometer reached its lowest reading, 29.38 inches, while the wind fell calm and the rain ceased; very heavy nimbus clouds traveled overhead at a high speed from the southwest and a high, short, and dangerous sea from the northeast, caused the ship to pitch heavily and made it necessary to let her head fall off to the east in order to make headway, the ship being very light. At 6:30 p. m. a light breeze came out of the south-southwest and the barometer rose to 29.43 inches, clearly indicating that the center had passed. At 7 p. m. the wind increased to a strong south-southwest gale, with excessive rain beating down the northeast sea and enabling us to return to our course, northeast one-quarter east. At 8 p. m. the barometer stood at 29.58 inches, with a moderate gale hauling gradually southward. After two heavy squalls at 10 p. m. the weather cleared; barometer 29.73 inches, steadily rising; sea coming up from south-southeast; sky clearing and stars shining out again; strong breeze hauling to east. And so finished this little storm which showed all the symptoms of a genuine West Indian hurricane undeveloped, with the exception of the sea in the vortex, which, instead of being confused, came almost suddenly from the northeast, and remained from that quarter until the wind and sea from the receding semicircle overwhelmed it. Captain Spedding, who has been in this particular trade, from Europe to the river Amazon, for many years, and many others on board who have been long acquainted with these regions, say they have never experienced any weather of a cyclonic character so far to the eastward before.

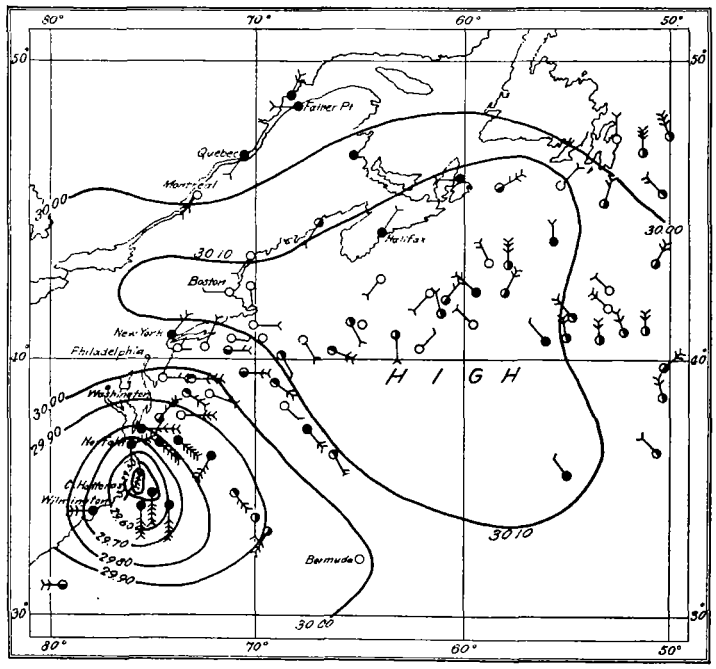

FIG. 14.—Greenwich noon, August 18, 1899.

From the foregoing log it appears that when the *Grangense* encountered the hurricane its development was not complete. The exceedingly low barometer which characterizes the tropical storm in its maturity was lacking, and neither the winds nor the sea had as yet attained dangerous violence. At the same time, according to the above account, this storm

"showed all the symptoms of a genuine West Indian hurricane undeveloped." There was a well defined storm area, with low barometer and calm center, and a complete cyclonic circulation of the winds, together with heavy rainfall. Four days later, when the hurricane reached Montserrat, the area of the storm had increased; the barometer was almost two inches lower, having fallen to 27.45 inches; the winds blew with hurricane force, causing immense damage and loss of life, and the rainfall was excessive. The storm which the *Grangense* encountered in its infancy had become the fully developed hurricane whose destructiveness will make it ever memorable in the annals of Porto Rico.

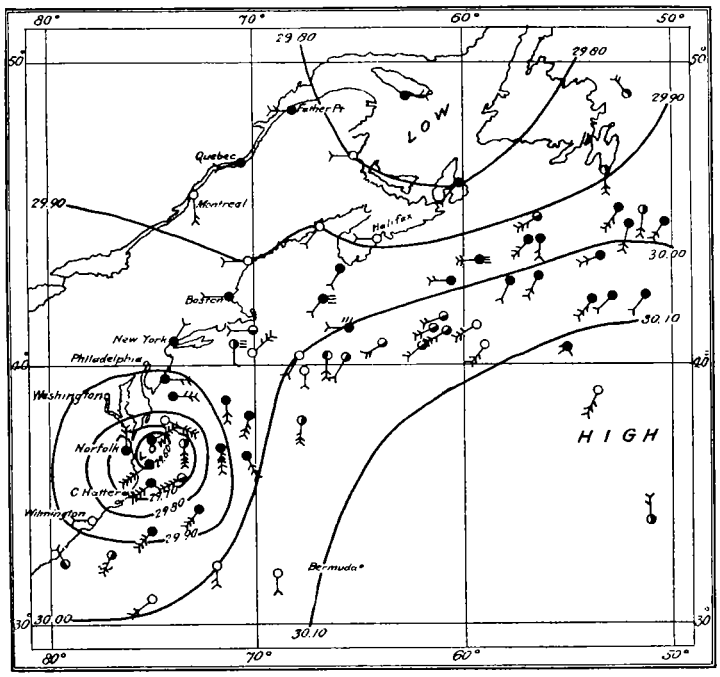

FIG. 15.—Greenwich noon, August 19, 1899.

The place of origin of this storm is as yet undetermined. The stage of development which it had reached on August 3, however, indicates that it originated as far eastward, at least, as the longitude of the Cape Verde Islands.

The hurricanes of the West Indies have been observed since the discovery of America, and lists of these storms covering the last four hundred years have been tabulated. It was not, however, until the present century that Redfield (and especially the international work since 1873,) collated sufficient observations to enable us to trace these hurricanes and ascertain approximately their life history. The period embraced between the birth of those tropical storms that originate to the east of the West Indies and their disappearance from the North Atlantic Ocean ranges from ten to twenty days, the average being less than fifteen days. Reference to the track of the late Porto Rican hurricane, which appears upon the accompanying chart, giving the positions of the center at successive Greenwich mean noons, shows that its length of life greatly exceeded that of any other whose records are sufficiently complete to justify a comparison and lasted almost three times the average period. From August 3, when the storm was encountered by the *Grangense*, until September 7, when it passed from the North Atlantic to the eastern coast of France, there is embraced a period of thirty-six days. This remarkable longevity has a close connection with the exceptional path of the hurricane and its slow velocity.

When the storm was reported by the *Grangense*, latitude 12° 40′ north, longitude 35° west, it was moving west by north. Its course gradually became more northerly, reaching a northwesterly direction in the Bahamas. Off the coast of Florida the storm recurved and was moving northeasterly in the vicinity of South Carolina. From August 3–7 the hurricane had a velocity of 20 miles an hour, and from the Lesser Antilles to Porto Rico, 16 miles. Between Porto Rico and the storm's position off the Carolinas on the morning of August 16 its rate of movement was 9 miles an hour, having suffered the usual retardation due to the American coast. Up to this point the storm's velocity and course may be considered normal, and it was to be expected that it would continue in a northeasterly direction, greatly increase in velocity and area, and move rapidly over the Grand Banks, disappearing to the north of the fiftieth parallel. Instead, the storm changed its course to north by west, slowed down during August 16–19 to a rate of 3 miles an hour, and remained practically unchanged in area. The recurving of the hurricane brought its center near the shore in the neighborhood of Hatteras, causing, for this reason, greater damage here than elsewhere along the coast of the United States, being specially destructive to shipping. On August 19 the storm moved seaward with increased velocity and with a general easterly direction. During the week of August 24–30 it remained almost stationary near the forty-fifth meridian, the center on August 26–28 shifting westward and northward. To the east of the Azores the storm curved northeastward, bending to southward near the fifth meridian west. On September 9 it was central off the coast of Provence, France, gales prevailed in this region until September 12, on which date the storm apparently had united with an area of low barometer covering southeastern Europe.

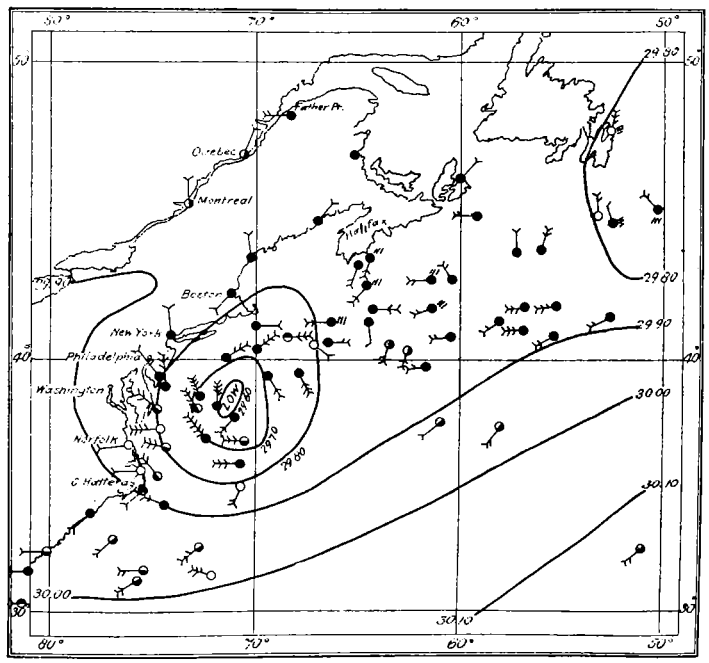

FIG. 16.—Greenwich noon, August 20, 1899.

Barometric readings below 29 inches and winds of hurricane force were frequently reported during the storm's passage through the West Indies and along the coast of the United States. Observations of the hurricane during its course in recrossing the Atlantic show a slight decrease in the violence of its winds and a diminution in the depth of the barometric depression, but one reading below 29 inches having been reported; however, whole gales and winds of storm force were still encountered. San Miguel, Azores, had a minimum barometric reading of 29.08 inches; the storm at this island caused much damage to property, besides with the reported loss of several lives. The log of the French steamship *Château Lafitte*, which vessel met the storm of September 6 in latitude 46° north, longitude 8° west, shows that on that date it

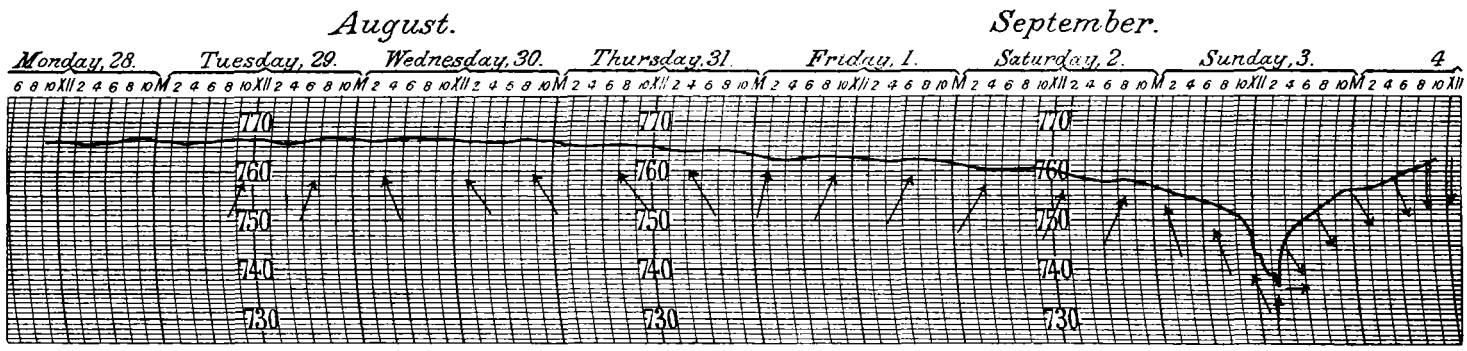

FIG. 17.

had lost but little of the severity which it exhibited within the Tropics. The *Château Lafitte* reports: "At noon the wind blew almost a hurricane from the southwest; sea very heavy from the same direction; barometer, 29.50 inches."

While the hurricane was central over the Lesser Antilles, the radius of the area within which the winds reached gale force was approximately 100 miles. Along the coast of the United States the radius had increased, ranging from 150 to 250 miles. In mid ocean the average radius was 200 miles, decreasing materially by the time the storm reached the coast of France.

The accompanying barogram, fiig. 17, furnished the Hydrographic Office through the courtesy of Capt. F. A. Chaves, Director of the Meteorological Observatory at Ponta Delgada, San Miguel, Azores, shows the shifting of the wind and the movement of the barometer during the passage of the storm over that place. The barogram points to a still lower minimum for Ponta Delgada than the one given above. The storm apparently passed almost over this town, slightly to the northward.

The daily charts of Atlantic weather show that both off the coast of the Carolinas and between the fortieth and fiftieth meridians, where the movement of the center of the storm was slow and irregular, areas of high barometer were present to the northward. The conditions of the wind and weather in the former case are shown by the accompanying synoptic charts for August 17–20. (See figs. 13, 14, 15, 16.) The observations on these charts were taken at noon, Greenwich mean time, which corresponds to 7 a. m., local time, on the seventy-fifth meridian. The general track is shown on Chart XIII.

On August 15 an area of high barometer covered the Great Lakes and Ontario with a maximum reading of 30.35 inches. The decrease in the rate of the storm's movement was coincident with the southeastward passage of this high, as is shown by the synoptic charts. On August 17 the position of the high is directly to the north of the storm area. On August 20 the high had decreased in height and moved to the eastward of the fiftieth meridian; the storm had moved off the American coast and increased in velocity.

In these charts the isobars are drawn for every tenth of an inch apart. The following symbols are used: ⚲, clouds not given; ↖, variable winds, force 2.

NOTES BY THE EDITOR.

THE WEATHER BUREAU AT THE PARIS EXPOSITION.

The Editor has received from Mr. F. J. Walz, in charge of United States Weather Bureau exhibit, an early proof of an article prepared by Mons. L. Barri, Adjunct Astronomer at the Paris Observatory, for publication in the Revue Scientifique. M. Barri makes an extended comparison between the daily publications of the Weather Bureau and those of the Central Meteorological Bureau of France. He says that the comparison between the two must be made indulgently in view of the fact that the funds at the disposal of the Weather Bureau are much larger than those available to our French colleague. Our daily weather map is more than six times as large as that of the French Bureau. The number of stations appearing on our weather map is nearly twice as many. The data given on it is nearly all presented graphically, while on the French map that which is missing is given in tabular form in the accompanying bulletin. The percentage of verifications of storm signals is nearly the same in France as in America, but in general the predictions do not extend so far in advance as do our own.

Mr. E. G. Johnson, assisting Mr. Walz, forwards an article contributed by Dr. Henry de Varigny to Le Temps of September 13, in which he praises the work of the Weather Bureau of the United States and the graphic view of its organization that one obtains from its exhibit at the Exposition of 1900. After describing quite completely the daily processes of observation, enciphering, telegraphy by the circuit system, deciphering or translation, the production of maps both manuscript and printed, and the distribution of weather predictions and storm warnings. He says:

> No one can ignore the fact that the work of the Weather Bureau is very helpful in the prediction of the weather in Europe, since the weather advances from west to east, and it is from America that the areas of low pressure, which extend rapidly, come to us and make confusion in our meteorology. It is the same in the United States, the future weather is determined by the conditions that prevail in the western portion of that continent.

Although this latter statement by Varigny may in general be true, yet the practical work of daily forecasting has long since shown that one has to keep a steady watch northward, southward, and eastward for the perturbations that disturb the progress of the weather from west to east.

In a detailed report by Mr. F. J. Walz, dated October 18, 1900, and after giving a very full catalogue, filling ten pages, of the Weather Bureau exhibit at the International Exposition of 1900, he says:

> The United States Weather Bureau exhibit was installed during the month of April and opened to visitors for inspection in completed condition May 15. The building remained open and the exhibit accessible to visitors every day, except Sundays, from 9 a. m. to 6 p. m. during the time from May 15 to September 30, and from 9 a. m. to 5:30 p. m. during the month of October. It was necessary to close a half